Feeding Activities of *Tegula funebralis*

(Mollusca: Gastropoda)

BY

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(1 Text figure; 3 Tables)

INTRODUCTION

The intertidal regions at China Point, Pacific Grove, California, provide an abundance of marine plants for a dense population of the primarily herbivorous gastropod *Tegula funebralis* (A. Adams, 1854). With the variety of plant foods available, *T. funebralis* could be expected to display preferences. Feeding activity of the large snail population (400/m²) could certainly affect the algal crop within the *T. funebralis* zone. Leighton (in press) has established food preferences for several sublittoral benthic grazers and his extensive field observations have shown the profound effect of grazing activities on the standing algal crop.

The possible food sources of *Tegula funebralis* fall into three categories: rock encrusting algæ, macroscopic plant forms, and organic detritus (see Fox, 1957, pp. 383-390) on the predominantly granite surfaces. In addition to the

food sources, preferences, and the animal's effect on the littoral algal crop, a quantitative estimate of the food consumed by the snail under laboratory conditions was obtained. Light was investigated as a possible factor.

METHODS AND DATA

1. **Food source determination:** One to 3 grams of an alga (or stones covered with an encrusting form) were placed in plastic dishes containing 2 animals (5 to 10 grams each, wet weight, with shell). The dishes, located in a greenhouse, were continuously supplied with running seawater at 14° C. Any ingestion of the food was noted after 24 hours. Significant weight loss of the alga, fragmentation, evidence of radular rasping, or identification of the food in the gut or fecal material was used to determine whether or not ingestion had occurred. All animals and foods used were taken fresh from the field. The plants listed in Table I were ingested in varying amounts and are therefore considered food sources.

A simplification of the organic carbon determination in the Manual of Seawater Analysis (Strickland & Parsons, 1960, pp. 117-121) was used to measure the organic detritus, or leptopel, on the granite surfaces, and therefore the availability of leptopel as a food source. Samples were collected by placing a plastic cylinder upright against the granite surfaces, sealed at the base with plasticene modeling clay. Five ml of 1.0 N. NaOH and 3 to 5 ml distilled water washings were successively poured into the sampling cylinder. This was accompanied by light scratching on the rock surface with a glass rod to simulate the rasping of *Tegula funebralis*. One ml of 70% phosphoric acid was added to the sample and heated for 30 minutes in a boiling water bath, followed by 10 ml of potassium dichromate in sulfuric acid solution and 60 minutes of additional heating. After making up to 50 ml volume with distilled water, the sample was read on the Klett colorimeter, supplied with a blue filter. The result is given in μg of carbon, taken from a standard curve of glucose carbon. The samples were taken from barren rocks, 3 to 4 feet above MLLW.

Using the same technique, the organic carbon content of a sandstone sample (surface scrapings down to 2 mm) was found. The stone was taken from the intertidal area on the north side of Punta Banda near Ensenada, Baja California, and is probably a food source for the local *Tegula gallina* (Forbes, 1850) population. This warm water region has an almost exclusively sandstone substrate with a few patches of brown filamentous algæ. Examination of the fecal material from several *T. gallina* showed approximately 80% sandstone by volume. The remaining 20% contained fragments of the filamentous algæ.

The organic content of four granite surface samples averaged 57 μg C/cm², ranging from 22 to 67 μg C/cm².

Table 1

Plant foods ingested by *Tegula funebralis*

Cladophora sp.	*Macrocystis integrifolia*
Corallina sp.	*Nereocystis Luetkeana*
Egregia Menziesii	*Pelvetia fastigiata*
Chaetomorpha sp.	*Peyssonnelia pacifica*[1]
Endocladia muricata	*Phyllospadix Scouleri*
Gastroclonium Coulteri	*Prionitis lanceolata*
Gelidium sp.	*Ralfsia pacifica*[1]
Gigartina Aghardii	*Rhodoglossum affine*
Gigartina canaliculata	*Ulva sp.*
Iridaea flaccidum	Unidentified unicellular green
Lithothamnion sp.[1]	alga growing on rocks[1]
	Diatoms

[1] Encrusting alga

Authorities for these names are given in Smith (1944)

The four sandstone samples averaged 2110μg C/gm, with a 2000 to 2240 μg C/gm range.

2. Food preference determination: Preference experiments were restricted to the macroscopic algæ. Plastic dishes were again used in the greenhouse. Three sets of algæ were offered on alternate days to the same animals, which had been collected one day before starting the series of tests. The four species of algæ in each set were placed, in combinations of three, in the dishes with either 10 small animals (range 1 to 4 grams), or 5 larger (range 6 to 12 grams). Wet weight differences of the algæ to the nearest 0.1 gram were taken after 24 hours. Control dishes showed no appreciable change in wet weight of any alga (maximum of 0.03 grams). Results are shown in Table 2.

3. Feeding rates: *Macrocystis integrifolia* blades were selected for the feeding rate determination because of the accessibility of its large blade area and its apparent appeal to *Tegula funebralis*. Animals collected in the field were fed *M. integrifolia* for 36 hours before beginning. The wet weight of the alga consumed was measured 6 times at intervals of 8 to 25 hours for a total of 82 hours. Two size ranges of the snail were again selected (3 to 5 and

Table 2

Food preferences of *Tegula funebralis*
(Grams of plant consumed in 24 hours)

Experiment	1				2				3			
Number of animals	A	B	C	D	E	F	G	H	I	J	K	L
10	0.3	0.2	x	0.0	2.0	0.1	x	0.0	2.5	0.1	x	0.1
10	0.5	x	0.1	0.0	x	0.1	0.1	0.1	x	0.0	0.0	0.0
10	0.5	0.2	0.2	x	2.1	0.0	0.0	x	2.5	0.2	0.0	x
10	x	0.3	0.1	0.1	2.1	x	0.0	0.0	2.6	x	0.0	0.1
Total eaten	1.3	0.7	0.4	0.1	6.2	0.2	0.1	0.1	7.6	0.3	0.0	0.2
Number of animals												
5	0.2	0.1	x	0.0	2.2	0.1	x	0.0	3.0	0.1	x	0.0
5	0.7	x	0.1	0.1	x	0.0	0.2	0.0	x	0.1	0.1	0.0
5	0.5	0.2	0.1	x	2.7	0.1	0.0	x	2.7	0.0	0.0	x
5	x	0.3	0.1	0.0	2.2	x	0.0	0.0	2.6	x	0.0	0.0
Total eaten	1.4	0.6	0.3	0.1	7.1	0.2	0.2	0.0	8.3	0.2	0.1	0.0

A *Gigartina canaliculata*
B *Rhodoglossum affine*
C *Endocladia muricata*
D *Iridaea flaccidum*
E *Macrocystis integrifolia*
F *Corallina sp.*
G *Pelvetia fastigiata*
H *Gigartina Aghardii*
I *Nereocystis Luetkeana*
J *Cladophora sp.*
K *Phyllospadix Scouleri*
L *Prionitis sp.*

x = plant omitted from set

7 to 9 grams) with four animals in each dish. Results are converted to grams of the alga consumed per day per gram wet weight (with shell) of *T. funebralis* (Table 3). The control algæ showed a maximum wet weight change of 0.02 grams.

4. Effect of grazing on the littoral algal crop. For this short period study (17 days), wire mesh cages, 50 x 50 x 20 cm, were fastened over the substrate with the bases flush to the rocks. Four cages were placed adjacently (2 in each of 2 areas). *Tegula funebralis* was excluded from one cage and 200 to 300 animals were enclosed in the adjacent cage of each area. At the end of the study, the only appreciable changes that occurred were: a) noticeable grazing on *Rhodoglossum affine, Gelidium sp.,* and *Iridaea flaccidum*; b) the appearance of *Ulva sp.* in one of the cages without animals (the alga was found nowhere else within a radius of over 3 meters).

DISCUSSION

Though *Tegula funebralis* will ingest almost any common alga, it displays definite preferences among the macroscopic forms, i.e. *Macrocystis integrifolia, Nereocystis Luetkeana, Rhodoglossum affine.* and *Gigartina canaliculata.* In each case, the preferred alga is a "fleshy" form. It is non-calcareous, nonfilamentous, and has a tender thallus contrasted to the leathery texture of *Gigartina Aghardii* and *Pelvetia fastigiata.* The preferences are consistent in the two size groups of *T. funebralis.*

Since the highly preferred giant brown algæ are normally available to the snail population only as drift material, the food sources of the animals include plants growing outside the *Tegula funebralis* zone. This is supported by a field situation at a site of organic detritus sampling. The *T. funebralis* population at this location dwells on extremely barren rocks and is apparently nourished by the considerable quantities of drift seaweeds that accumulate.

The encrusting algæ, particularly the abundant green alga and *Ralfsia pacifica,* are undoubtedly important in the diet of the animal. As Figure 1 illustrates, the width of the rasping pattern on a glass plate thinly coated with diatoms greatly exceeds that found on a thick *Macrocystis integrifolia* blade showing an efficient mechanism for covering a large surface area when necessary. This may also be important in keeping larger algae free of diatom growth.

Organic detritus on granite surfaces is probably only an incidental food source at best. The detritus does contain digestible compounds, however (see Nigrelli, 1963, pp. 9-11). *Tegula gallina* undoubtedly utilizes the organic content of its sandstone substrate in a manner similar to

Table 3

Feeding rates of *Tegula funebralis*

animal weight gms *		hours in test periods						amount consumed		
										gms
								total	gms	gm*
total	range	8.3	25.5	11.5	12.6	12.5	11.5		day	day
Sunlight										
33.1	7-9	0.18	0.14	0.35	0.16	0.18	0.12	1.13	0.33	0.010
34.9	7-9	0.08	0.28	0.64	0.13	0.12	0.05	1.30	0.38	0.011
15.5	3-5	0.06	0.25	0.38	0.00	0.11	0.10	0.90	0.26	0.017
14.9	3-5	0.17	0.20	0.10	0.12	0.12	0.07	0.78	0.23	0.015
Constant Darkness										
32.1	7-9	0.03	0.26	0.45	0.02	0.01	0.30	1.07	0.31	0.010
33.7	7-9	0.14	0.00	0.00	0.20	0.01	0.12	0.47	0.14	0.004
15.1	3-5	0.00	0.19	0.25	0.11	0.07	0.07	0.69	0.20	0.013
16.3	3-5	0.05	0.38	0.02	0.06	0.28	0.13	0.92	0.27	0.017

Numbers represent the grams of *Macrocystis integrifolia* consumed in the given time period. Horizontal rows give data for 4 animals, with total weights and individual ranges (3 to 5 gms or 7 to 9 gms.)

*(in wet weight of animals, with shell)

Littorina planaxis (PHILIPPI, 1847) and *L. scutulata* (GOULD, 1849) as shown by NORTH, 1954. In earlier work, NORTH (unpublished data) measured the erosive activities of *T. funebralis* on sandstone. He collected 1.1093 gms of eroded (ingested) sandstone from the fecal material of 11 snails (total weight 58.4 grams) in 24 hours. Organic detritus, as found in sandstone, may therefore be included as a food source of *T. funebralis* as well as *T. gallina,* though sandstone is not found in the China Point area.

Table III clearly shows that the larger snails have a lower feeding rate (in grams consumed per gram of animal) than the smaller snails. The overall difference of 17% in feeding rate found between sunlight and constant darkness is too small to suggest a photokinetic response in feeding activity. The mean feeding rate in light (0.012 gm/gm of animal/day) probably represents the maximum found in the field, since the food was available in excess and shown to be highly preferred.

The condition of the algæ in the cages at the end of the 17 day period (in experiment 4) verifies the preferences determined in the laboratory. Each of the species of algæ affected (except possibly *Ulva*) could be called a "fleshy" form. A definite relationship between the *Tegula funebralis* population and the marine plants in its environment is certainly indicated.

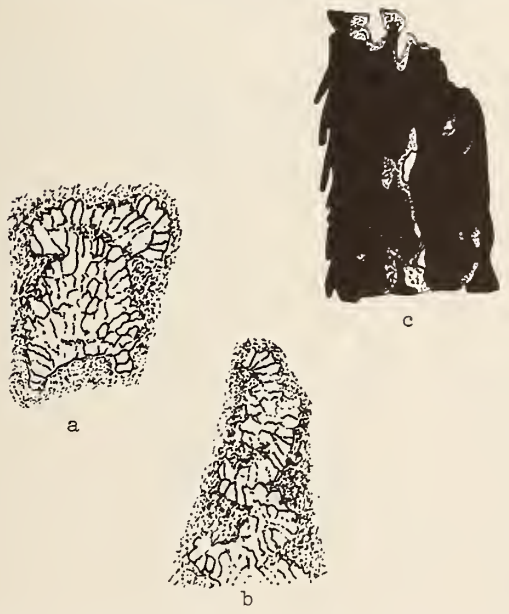

Figure1: Rasping patterns produced by *Tegula funebralis.* a, b: on glass plate, thinly coated with diatoms; c: on blade of *Macrocystis integrifolia.* (all x $\frac{4}{5}$)

SUMMARY

1) *Tegula funebralis* will ingest nearly any alga growing in or out of the littoral zone. Both macroscopic and encrusting forms constitute important food sources; the granite surfaces contain a negligible amount of organic detritus and contribute little to the diet of the animal. Earlier work on *T. funebralis* and observations of *T. gallina* show that the animals will ingest organic detritus when it is available.

2) The snail prefers a "fleshy" alga among macroscopic forms (e.g. *Macrocystis integrifolia, Nereocystis Luetkeana,* and *Gigartina canaliculata).*

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3) Feeding rates per gram are greater in the smaller animals and are apparently not affected by lack of sunlight.

4) A short field study suggests the importance of the feeding activities of *Tegula funebralis* on the local algal crops.

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